

28 September 1967

MEMORANDUM FOR THE RECORD

SUBJECT: The Direct (Virtual) Image Viewer

In order that the reader fully understand this discussion, he should review the following terms to be aware of their specific meanings: real image, virtual image, diffraction grating (particularly the differences between phase and amplitude gratings), exit pupil, microscope (the optical system involved), diffusion, diffraction, opaque, translucent, transparent.

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From talks with various operators of this instrument, we became aware that there had evolved considerable confusion about the nature of the direct image viewer. To help clarify this situation, we have consulted the original contract notes and used them as the basis for our investigations and the ensuing discussion.

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The basic objectives for the viewer are outlined in a report entitled "Direct Image Viewer, Specifications for", prepared by [redacted] dated 25 August 1964. According to page one of this report

"The Direct Image Viewer employs a unique optical approach, involving diffraction gratings, to provide the observer with an enlarged aerial image which can be viewed simultaneously with both eyes. Major features of this viewer include the elimination of performance limitations imposed by the use of rear projection diffusion screen and the achievement of high magnification viewing qualities comparable to microscopic viewing objectives."

*to whom addressee*

Note that the viewer is designed to be used by a single person and that it is implied that diffusion material is not to be used. Since no diffusing material is to be employed, the only way that an image could be viewed would be for the viewed image to be virtual. Hence, the label "Virtual Image Viewer" is perfectly legitimate and accurate.

The optical design of the viewer is analogous to a rather large microscope which has been modified by adding a diffraction grating between the "ocular" and the "objective lens". A field flattening lens has also been added between the grating and the objective lens since diffraction must occur from a plane image. The theoretical results of these modifications are the creation of a field of adjacent exit pupils, 3 1/2 inches by 3 1/2 inches, of uniform intensity,

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through which the operator would look when viewing imagery.

Unfortunately, these theoretical results were not realized as there did not exist a suitable diffraction grating. In fact much of the effort expended on the development of the viewer has centered around the creation of such a grating, as is evident from the available contract notes. Using photographic techniques, EDL undertook the search to develop and produce a phase grating having the desired properties; however, a suitable diffraction grating of this type was never actually produced. [REDACTED] was officially contracted to produce a ruled grating and it is with this grating that the machine was delivered.

In its present configuration with the [REDACTED] grating, the viewer presents the operator with a rather complex combination of a real and a virtual image (i.e., it is acting as a rear screen projector and a microscope simultaneously). This is because of the nature of the grating, which consists of crossed alternating stripes of [REDACTED] lines on a transparent surface. These ruled lines, which are actually translucent, act as diffusing areas when placed in the viewer. Because a real image is focused in the same plane in which the [REDACTED] ruling is mounted, a real image is formed on the ruled surfaces and transmitted through it. In addition to forming this real image, the grating is diffracting the light, causing the formation of the multiple aperture field through which the virtual image can be seen. Thus the operator has two types of images of different quality displayed in front of him when he looks into the machine. It is important to note here that the image plane of the virtual image and the image plane of the real image are not coincident.

The most significant visual detriment from the operator's point of view is a plaid effect which at first glance seems to be superimposed on the two images. This plaid pattern appears to move as the operator moves his head while looking through the aperture field. This is very distracting. As the eye approaches the plane of the exit pupil field, the plaid expands and actually disappears when the eyes are positioned so that the aperture of each eye is completely contained within a single exit pupil from the field. A person operating the machine can easily demonstrate this to himself. When the diffraction grating is replaced with a diffusing screen, the plaid pattern disappears, thus indicating that the effect is indeed a result of the diffracted light and is adherent to the displayed virtual image. Although the exact cause of the pattern is not known, it is felt that it results from certain peculiar physical properties of the [REDACTED] diffraction grating.

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Some of these various points are illustrated in the polaroid photograph (#1) which shows the aperture field with the outline of the grating mask and the diffused light from the [redacted] grating STATINTL background. The grating mask is visible because diffuse light is being scattered randomly from the surface of the grating. For the purpose of comparison your attention is next directed to the lone aperture illustrated (#2). This is the lone exit pupil that is formed when there is no grating in the system. If a "perfect" grating existed, it would produce an even field of these apertures. Since the aperture edges would be exactly adjacent, this would give the appearance of a single large aperture. Also, for comparison, note the picture showing the field of apertures of varying intensities (#3). You will see that there is very little diffused light and that the outline of the grating mask is not visible because no real image is being formed in that plane. The ruling in this case is a Ronchi ruling which was hastily made on Kodalith in an effort to demonstrate a diffraction material which does not also act as a diffusing screen. Note that the intensity in each exit pupil is less intense than in the figure showing the single exit pupil. This is because the Ronchi ruling is an amplitude grating rather than a phase grating and as such passes only 50% of the light incident upon it. In its present configuration, the machine is usable provided the operator holds his head in a specific fixed position within the exit pupil field plane. At this certain position the "moving plaid" effect is not noticeable and the real and virtual images coincide. Some sort of hood or a simple head positioning device could be installed to aid the observer.

The search could be continued to produce a "perfect" diffraction grating; however, this author feels that rather than pursue phase grating studies, amplitude gratings should be investigated. Amplitude gratings are relatively easy to make and would require nothing that is currently beyond the state-of-the-art. It is possible that an amplitude grating that would allow an acceptable level of light to pass and have the required diffraction properties might be feasible.

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**Approved For Release 2001/07/16 : CIA-RDP78B04747A001100010005-4**

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MEMORANDUM FOR: Development

Here are the three photographs that go with  
the Direct (Virtual) Image Viewer memorandum.

*Do you have the  
menu?*

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5 October 1967  
(DATE)

FORM NO. 101 REPLACES FORM 10-101  
1 AUG 54 WHICH MAY BE USED.

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